Bangladesh Journal of Animal Science 53 (2): 68 - 76, 2024 https://doi.org/10.3329/bjas.v53i2.74541

Bangladesh Journal of Animal Science
Journal homepage: http://www.banglajol.info/index.php/BJAS

Inclusion of dietary lysine on growth, carcass yields and serum biochemical indices in broiler chickens

B Dey[1], S Akhter[1], HA Hasan[1], LK Tanim[3], MR Sikder[2], M Ahammed[1]✉

[1]Department of Poultry Science, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

[2] Managing Director, Apeel Science, Dhaka, Bangladesh
[3]Faculty of Animal Husbandry, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh

ARTICLE INFO

Article history:
Received: 18 May 2024
Revised: 4 June 2024
Accepted: 23 June 2024
Published: 30 June 2024

Keywords:
Lysine, broiler, growth performance, carcass yield, blood parameters

Correspondence:
M Ahammed✉:
musabbir.ps@bau.edu.bd

ISSN: 0003-3588

OPEN ACCESS

ABSTRACT

The experiment was conducted to compare the effect of different sources of lysine on growth performance, carcass yields and serum biochemical parameters in broiler. A total of 400 Arbor Acres straight run chicks were randomly assigned into 4 different treatment groups for five weeks. The treatment groups were; T_1 (100% Ajinomoto lysine), T_2 (100% CJ lysine), T_3(100% Natural lysine) and T_4(50% Ajinomoto + 50% Natural lysine). Each treatment consisted of four replicates and of each 25 chicks. Throughout the experiment body weight, body weight gain, feed intake and feed conversion ratio were recorded as growth performance. Carcass characteristics and blood biochemical profile were also taken after the end of feeding trial. The supplementation of different sources of lysine with feed had significant ($P<0.05$) effect on growth performances. Results showed that CJ lysine treated broilers had significantly ($P<0.05$) higher body weight and body weight gain at the end of the experiment compared to Ajinomoto and Natural lysine treated groups. FCR was improved significantly ($P<0.05$) in CJ lysine group (1.56) compare to the Ajinomoto group (1.69) and Natural lysine group (1.68). Abdominal fat weight showed significant ($P<0.05$) variation among different treatment groups. Based on the results of this study, it may be concluded that the supplementation of Ajinomoto lysine, CJ lysine and Natural lysine with feed could improve growth performance of broiler and CJ lysine could be considered as performance enhancer in broiler production.

Introduction

The diets of chicken must contain amino acids in large quantities. Amino acids are crucial for the body's structural and defensive tissues as well as for the proper functioning of enzymes and tissues (NRC, 1994). The essential amino acids for poultry are Arginine, Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan, and

How to Cite

B Dey, S Akhter, HA Hasan, LT Tanim, MR Sikder and M Ahammed (2024). Inclusion of dietary lysine on growth, carcass yield and serum biochemical indices in broiler chickens. *Bangladesh Journal of Animal Science* 53 (2): 68 - 76. https://doi.org/10.3329/bjas.v53i2.74541

Valine (Mc Donald, 2007). Lysine improves broiler performance, overall growth, feed conversion ratio (FCR), and survivability. Also, it is crucial for hens that are unable of maintaining biological process and growth. Lysine is available in a variety of forms; its typical appearance is that of a fine white powder or fine grain particles with a crystal-like structure. It readily dissolves in water, which has contributed to its appeal in the supplement industry due to how simple it is to incorporate into powdered drink mixes. The body needs lysine to produce creatine monohydrate, which is necessary for both energy production and muscle growth. L-lysine HCL (Feed grade) which brand is Ajinomoto or CJ used for animal consumption. It is made in Brazil under license of Ajinomoto Co., Inc., Japan. It is produced by an innovative fermentation process. Raw materials such as corn, tapioca and sugarcane are used, then through strain development, fermentation, purification and drying process the final product (L-lysine HCL) is manufactured. It has 3 physical forms; powder, granule and liquid form. Powder form has higher purity (99%) than other two forms. Few ingredients used in making chicken diets typically do not contain enough lysine. Thus, it is necessary to add synthetic lysine to the nutritional combination to make sure the birds get a suitable quantity. All high-quality chicken feeds are made to include enough lysine to promote healthy body growth and the formation of feathers. However, if extra grains (like maize) are included in the full meal, the amount of lysine that the bird consumes may not be sufficient to support growth, in addition to other physiological processes and immune responses. To meet the nutritional requirements of the birds, lysine must be added to broiler diet. For the regulation of nitrogen and carbohydrate metabolism, as well as for the production of nucleotides and chromo proteins, lysine is essential for poultry. It encourages the rapid growth of young birds, the high consumption of feed, and the production of the melanin pigment in chicken feathers. Lysine impacts erythrocyte production, calcium deposition in bones, and redox processes. It also activates amino acid transamination and deamination, which makes it easier for the body to absorb calcium and phosphorus. The synthesis of proteins, particularly those important for the development of skeletal tissue, enzymes, and hormones, more effectively utilizes the available lysine. At the same time, lysine can be broken down to produce glucose and ketone bodies when there aren't enough readily available carbohydrates. While poultry is fasting, this mechanism serves as a significant energy source. Low abdominal fat pad weight was found to be associated with improved FCR, breast meat production, and BWG at an optimal lysine concentration of 1.09% greater than NRC norms (Leclercq, 1998). When broiler chickens were provided finisher food supplements with lysine, their growth performance was found to be significantly improved (Leclercq ,1998; Razaei *et al.,* 2004; Sterling *et al.,* 2004). The aim of the present study was to investigate the effect of different source of lysine on growth performance, carcass yield and blood biochemical parameters on broiler chickens.

Materials and Methods

Experimental birds

A total of 400 day-old mixed-sex Arbor Acres commercial broiler chicks were used for this experiment. The chicks were collected from a reputed poultry hatchery.

Experimental diets

The broiler diet was formulated for three phases namely, starter, grower and finisher (Table 1). Three types of diets were provided as mash form. The nutrient requirements (ME, CP, CF, EE, Ca, P, Lysine and Methionine) were satisfied as recommended for Arbor Acres broiler strain diet and also same for all treatment.

Bird's management

A semi-monitor type open-sided house was used for the experiment. Sixteen (16) pens of similar sizes were made by using wire-net. Each pen area was 20 square feet (10 feet x 2 feet) containing 25 birds. The experimental house was properly cleaned, washed and disinfected by using disinfectant TH4+ solution (manufactured by Sogeval, France & distributed by Century Agro Ltd. Bangladesh). Rice husk was used as litter material at a depth of 3 cm. The day-old chicks were randomly placed in the pans and the initial body weights of the chicks were recorded. Glucose solution was provided to the chicks to overcome the transportation stress. The room was preheated

before the arrival of the chicks. A digital thermo-hygrometer was used to measure the temperature and humidity. The chicks were brooded in an enclosure with one 100-watt electric lamp. The chicks were supplied a temperature of 35°C during their first day, which gradually decreased every three days interval until they were one week old. The birds were exposed to a continuous lighting period of 23 hours, followed by 1-hour dark phase in the first 4 days of brooding. Feeds were first delivered on newspaper for the first four days of life, and thereafter on little trays. For each pen of 15 birds, one round tube feeder with a 3.5 kg feed capacity and one round drinker with a 4-liter water capacity were provided. After 7 days, the chicks were placed to the experimental site and feeders & drinkers are set as per need. The feeders and drinkers were fixed in such a way that the birds were able to eat and drink conveniently. Feeders were cleaned in every week and drinkers were cleaned two times daily (morning and afternoon). A standard vaccination schedule was practiced to maintain the flock healthy. To cope with the pressures of vaccination, catching for weighing, and other procedures, a fat-soluble vitamin called Allvit MA (BREMER PHARMA GMBH, Germany) was given to them in all treatments at a rate of 1 g per 1 liter of fresh drinking water. Strict bio-security procedures were maintained inside & outside the research shed.

Table 1. Ingredients and nutrients composition of the experimental diets (DOC – 35 days)

Ingredients	Starter (DOC – 14 days)	Grower (15 – 28 days)	Finisher (29 – 35 days)
Maize	53.25	56.25	60
Soyabean meal	27	23	21.75
Rice polish	6	6	5
Protein concentrate	8.5	8.5	4.5
Limestone	1	1	1
Di calcium phosphate	0	0	1
Lysine	0.238	0.24	0.25
Methionine	0.119	0.12	0.125
Vitamin premix	0.25	0.25	0.25
Enzyme	0.096	0.095	0.098
Choline chloride	0.1	0.12	0.125
Common Salt	0.447	0.425	0.402
Soyabean oil	3	4	5.5
Analyzed values of the nutrients			
Moisture (%)	10.34	10.64	10.39
ME (kcal/kg)	3063.65	3162.85	3243.53
CP %	22.36	20.88	18.16
Lysine %	1.51	1.40	1.20
Methonine %	o.52	o.51	0.45
Calcium %	0.86	0.85	0.63

Data collection and record keeping

All the data of birds' body weight, body weight gain, and feed intake were recorded weekly. Using this data, l body weight gain (BWG), feed intake (FI), feed conversion ratio (FCR) was calculated for each period of growth. During entire experimental period, the temperature and humidity of experimental house were recorded two times in a day (morning & afternoon) with the help of an automatic thermo-hygrometer. Each replicating bird had three to four ml of blood gently poured into sterile test tubes after being carefully drawn from the wing vein using a clean, sterilized disposable syringe and needle. For clotting, tubes were angled at a 45- degree angle and left at room temperature. After two hours, the separated blood serum was put into an eppendorf tube and centrifuged for ten minutes at

3000 rpm. After that, the serum was put into a different eppendorf tube and kept there at 20^{O}C until analysis. Permanent markers were used to appropriately mark the eppendorf tubes for simple identification during chemical analysis. According to their separate protocols, the serum lipid profile, which includes glucose, cholesterol, triglycerides, high density lipoproteins, low density lipoproteins, creatinine, total protein, and uric acid, was examined.

Statistical analysis

Analysis of Variance (ANOVA) was used to statistically assess all of the experiment's calculated and recorded data in accordance with the CRD principles (CRD). The significant differences between various means were determined using the Duncan Multiple Range Test technique at a 5% level of significance (SAS, 2009).

Result and Discussion

Growth performance

The overall growth performance of broiler has shown in Table 2. The results revealed that the dietary recommendations of Arbor Acres for lysine led to maximum growth performance, in terms of BW, BWG, FI, FCR. During the starter & grower periods throughout the study Ajinomoto lysine, CJ lysine, Natural lysine and the combined lysine (Ajinomoto + Natural) group did not affect broiler growth performance. These findings are in disagreement with Bahadur *et al.,* (2010) who reported that the supplementation of various sources of lysine had significant effect on body weight among treated groups. During the finisher period, a 0.05% difference among those treatment groups increased BW, BWG, FI, FCR which agrees with Emmert J L *et al.,* (1999). They showed different source of lysine had significant effect in body weight gain among treated groups. The findings of this study also agree with Ahmad *et al.,* (2007) that the supplementation of various sources of lysine had no significant effect on feed intake among treated groups. Additionally, the results supported by the observations of Zarghi *et al.,* (2020) who found that varying dietary lysine levels had no significant effect on feed intake. In overall period, better FCR was found in CJ lysine compared to other treated groups. The results were almost equal with Bahadur *et al.,* (2010) and Emmert J L *et al.,* (1999). They reported that the supplementation of various sources of lysine had significant effect on FCR among treated groups. In contrast to our findings, Ahmad *et al.,* (2007) showed that the supplementation of various sources of lysine had no significant effect on FCR among dietary groups. Some of these discrepancies might be due to the use of different experimental conditions, such as lysine levels/groups and experiment duration.

Carcass yields

The data of carcass yields have shown in Table 3. In this study dressing percentage, breast muscle, drumstick, head, shank and liver weight were also affected by supplemented lysine groups. Higher abdominal fat was observed at CJ lysine group compared to Ajinomoto lysine and Natural lysine groups. Moreover, there is no question that breast meat yield, as a major portion of the protein synthesis in the body, is very sensitive to essential amino acids of the diets specially in today's broiler strains which are genetically emphasized on high processing characteristics and breast meat yield. So, it is suggested that significant increasing breast muscle percentage and carcass efficiency in treatments with higher dietary levels of lysine group. Natural lysine group showed ($P<0.05$) significantly higher breast muscle parentage (40.05) compare to different treatment groups. The combined lysine (Ajinomoto + natural) group showed significantly ($P<0.05$) higher head (3.61%) and liver (3.61%) weight compare to other treatment groups. These findings agree with that of Tang *et al.,* (2007) and Ojediran *et al.,* (2018) and Bahadur *et al.,* (2010) who showed similar results using different sources of dietary lysine.

Serum biochemical indices

The results of serum biochemical indices have shown in Table 4. This result indicates that there were significant ($p<0.05$) differences in cholesterol, triglycerides, HDL, LDL and glucose among different treatment groups.

Table 2. Overall growth performance of broiler fed different sources of lysine (DOC-35 days)[1]

Parameters	Treatments				P-value	LS
	Ajinomoto lysine	CJ lysine	Natural lysine	Ajinomoto + Natural lysine		
DO weight (g/bird)	41.61±0.00	41.61±0.00	41.61±0.00	41.61±0.00	--	NS
Final Body weight (g/bird)	1293.28^{b} ± 10.72	1418.64^{a} ±11.33	1331.71^{ab} ± 11.99	1346.59^{ab} ± 8.93	0.000	**
Body weight gain (g/bird)	1251.68^{c} ± 10.72	1377.03^{a}± 11.33	1290.10^{bc} ± 11.99	1304.98^{b} ± 8.93	0.000	**
Feed Intake (g/bird)	2118.85 ± 23.72	2154.28 ± 19.12	2170.78 ± 24.59	2193.88 ± 15.55	0.095	NS
FCR	1.69^{a} ± 0.01	1.56^{b} ± 0.03	1.68^{a} ± 0.03	1.68^{a} ± 0.02	0.026	*

Data are presented as mean ± SE. Where, NS= Non-significant, LS= Level of Significance, *= Significant (P< 0.05); **=Significant (P<0.01). a, b and c mean with different superscripts within the same row differ significantly.

Table 3. Effect of feeding different sources of lysine on carcass yield of broiler (21 days & 35 days) (% in relation to body weight)

Age of birds	Parameters	Treatments				P-value	LS
		Ajinomoto lysine	CJ lysine	Natural Lysine	Ajinomoto + Natural lysine		
21 days	DP (%)	63.99 ± 1.05	67.89 ± 0.05	63.05 ± 1.83	61.31 ± 3.37	0.261	NS
	Breast Muscle (g)	39.50 ± 2.09	36.51 ± 0.95	32.52 ± 0.68	34.59 ± 1.13	0.076	NS
	Drumstick (g)	17.04±0.23	17.62±2.07	19.84±0.25	17.63±0.96	0.431	NS
	Head (g)	3.97 ± 0.01	3.87 ± 0.38	3.97 ± 0.11	4.22 ± 0.25	0.752	NS
	Shank (g)	9.90 ± 0.17	9.75 ± 0.86	11.89 ± 0.47	10.39 ± 0.72	0.191	NS
	Liver (g)	2.99 ± 0.11	3.32 ± 0.49	2.39 ± 0.07	2.88 ± 0.10	0.224	NS
	Abdominal Fat (%)	0.65^{b} ± 0.43	1.24^{a} ± 0.35	0.40^{c} ± 0.01	0.58^{b} ± 0.21	0.034	*
35 days	DP (%)	58.96 ± 1.88	59.05 ± 1.29	57.95 ± 4.29	55.31 ± 3.95	0.818	NS
	Breast Muscle (g)	32.99^{b} ± 0.49	34.98^{b} ± 2.08	40.05^{a} ± 0.43	36.38^{ab} ± 0.16	0.041	*
	Drumstick (g)	17.32 ± 1.44	17.00 ± 0.94	18.03 ± 0.34	18.39 ± 1.61	0.831	NS
	Head (g)	2.65^{c} ± 0.07	3.15^{b} ± 0.04	2.72^{c} ± 0.17	3.61^{a} ± 0.10	0.008	**
	Shank (g)	9.08 ± 0.93	10.53 ± 0.69	10.04 ± 1.19	10.57 ± 0.29	0.607	NS
	Liver (g)	2.86^{ab}± 0.15	2.47^{b} ± 0.34	2.62^{b} ± 0.07	3.61^{a} ± 0.10	0.046	*
	Abdominal Fat (%)	0.85^{b} ± 0.02	1.47^{a} ± 0.16	0.80^{b} ± 0.22	0.64^{c} ± 0.10	0.045	*

Data are presented as mean ± SE. Where, NS= Non-significant, LS= Level of Significance, *= Significant (P< 0.05); **=Significant (P<0.01). a, b and c mean with different superscripts within the same row differ significantly.

Table 4. Serum biochemical parameters of broiler in different dietary treatments (mg/dl)

Parameters	Treatments				P-values	LS
	Ajinomoto lysine	CJ lysine	Natural lysine	Ajinomoto + Natural lysine		
Cholesterol	$160.31^{b} \pm 5.31$	$233.75^{a} \pm 5.63$	$126.00^{c} \pm 5.25$	$151.56^{bc} \pm 5.94$	0.001	**
Triglycerides	$127.24^{ab} \pm 1.87$	$150.52^{a} \pm 3.95$	$110.07^{b} \pm 2.61$	$116.31^{ab} \pm 6.06$	0.007	**
HDL	$31.59^{c} \pm 1.19$	$34.44^{c} \pm 1.19$	$40.62^{b} \pm 4.50$	$50.61^{a} \pm 4.01$	0.043	*
LDL	$103.27^{b} \pm 4.49$	$171.21^{a} \pm 4.02$	$67.37^{c} \pm 2.73$	$103.29^{b} \pm 7.76$	0.001	**
Creatinine	0.78 ± 0.01	0.70 ± 0.14	0.94 ± 0.06	0.94 ± 0.17	0.440	NS
Uric acid	3.88 ± 0.19	4.76 ± 0.16	4.26 ± 0.10	4.28 ± 0.49	0.314	NS
Total Protein	4.18 ± 0.99	4.42 ± 0.14	4.25 ± 0.41	3.53 ± 0.40	0.725	NS
Glucose	$95.29^{bc} \pm 3.55$	$81.56^{c} \pm 4.76$	$111.38^{b} \pm 4.58$	$119.69^{a} \pm 4.65$	0.012	*
LDL/HDL ratio	3.27: 1	4.97: 1	1.66: 1	2.04: 1	--	--
Total Cholesterol/ HDL ratio	5.07: 1	6.79: 1	3.10: 1	2.99: 1	--	--

Data are presented as mean ± SE. Where, NS= Non-significant, LS= Level of Significance, *= Significant (P< 0.05); **=Significant (P<0.01). a, b and c mean with different superscripts within the same row differ significantly.

Broilers produce uric acid as the main end product of nitrogen metabolism (Hosseintabar *et al.,* 2015). In particular, birds metabolize excess or imbalanced dietary amino acids into various C-compounds and ammonia, and then convert the ammonia (which is highly toxic) into uric acid (Namroud *et al.,* 2008; Karami *et al.,* 2018). As precursors of L-carnitine, lysine can play important role in lipid and energy metabolism (Borum 1983). L-carnitine has hypolipidemic effects, in that it reduces circulating concentrations of cholesterol, triglycerides, free fatty acids, phospholipids, and VLDL, and it increases the concentrations of HDL, intermediate density lipoprotein (IDL), and LDL (Diaz *et al.,* 2000; Arslan 2006). Chickens experience significant increases in plasma cholesterol, LDL, and HDL when there are dietary surpluses of lysine (Bouyeh and Gevorgyan 2011). Our results indicate that CJ lysine group showed significantly higher ($p<0.05$) cholesterol and triglycerides compared to Ajinomoto and Natural lysine group. The combined lysine group showed significantly ($p<0.0.05$) highest except abdominal fat percentage. On the other hand, the serum biochemical indices vary significant among different dietary lysine sources. Taken together, it can be said that all the three dietary lysine sources (Ajinomoto, CJ, and Natural lysine) could be considered as performance enhancer for broiler and CJ lysine was better HDL and glucose compared to other dietary treatment groups. Natural lysine group showed significantly ($p<0.05$) lower LDL compare to Ajinomoto and Natural lysine group. On the other hand, serum creatinine, uric acid and total protein were not affected significantly among different dietary groups. Our results were supported by the observations of Yuan *et al.,* (2016). They showed dietary lysine had significant effect on blood biochemical parameters among different dietary treatment groups. But, Zarghi *et al.,* (2020) disagree with our results who found that dietary lysine had no impact on serum metabolites.

Conclusion

There were significant differences in terms of the growth performance of broilers fed different sources of lysine but the carcass yield characteristics were no differ statistically

performer than other two. But more details investigation will require using the combinations of different lysine source is necessary to draw a meaningful conclusion.

Acknowledgements
The authors would like to express their sincere thanks and gratitude to Apeel Science Bangladesh Limited for providing the lysine materials and necessary financial support to conduct the research. We also thankful to the department of Poultry Science for providing the logistic support for the smooth completion of the research.

Authors contribution
Bapon Dey plan, coordinate the whole research and review the manuscript, Musabbir Ahammed supervise the research, Ripon Sikder provided the test ingredients and logistic support, Sharmin Akter conducted the feeding trial, Hashib-A-Hasan prepare the draft manuscript and Lamia Khatun Tanim assist the feeding trial and help to prepare the manuscript.

Data availability
All the necessary data used in this research will be made available as per the authorization of the authors.

Conflict of interest
No conflict of interests regarding the publication of this paper.

Consent to participate
All authors have fully agreed to publish this research in Bangladesh Journal of Animal Science.

Consent for publication
All authors have fully agreed to publish this research in Bangladesh Journal of Animal Science.

References

Ahmad G, Mushtaq T, Aslam Mirza M. Ahmed Z 2007: Comparative bio- efficacy of lysine from L-lysine hydrochloride or L-lysine sulfate in basal diets containing graded levels of canola meal for female broiler chickens. *International Journal of Poultry Science* **86** (3) 525-530. https://doi.org/10.1093/ps/86.3.525

Araújo L F, Junqueira O M, Araújo C S S, Barbosa L C G S, Ortolan J H, Faria D E and Stringhini J H 2005: Energy and lysine for broilers from 44 to 55 days of age. *Brazilian Journal of Poultry Science* 4 237-241. https://doi.org/10.1590/S1516-635X2005000400007

Arslan C. 2006. L-carnitine and its use as a feed additive in poultry feeding a review. Rev Méd Vét. 157(3):134–142.

Bahadur V, Haldar S, Ghosh TK 2010: Assessment of the efficacy of L-lysine sulfate vis-à-vis L-lysine hydrochloride as sources of supplemental lysine in broiler chicken. *Veterinary Medicine International*, vol.2010, Article ID 964076, 9 pages, 2010. https://doi.org/10.4061/2010/964076

Baker D 1994: Ideal amino acid profile for maximal protein accretion and minimal nitrogen excretion in swine and poultry. Proc. Cornell Nutrition Conference for Feed Manufacturers, pp. 134-139.

Baker D H, Batal A B, Parr T M, Augspurger N R and Parsons CM 2002: Ideal ratio (relative to lysine) of tryptophan, threonine, isoleucine and valine for chicks during the second and third week of life. *Poultry Science* **81** 485-494. https://doi.org/10.1093/ps/81.4.485

Borum PR. 1983. Carnitine. Ann. Rev Nutr. 3: 233-259. https://doi.org/10.1146/annurev.nu.03.070183.001313

Café MB, Waldrop PW 2006: Interactions between levels of methionine and lysine in broiler diets changed at typical industry intervals. *International Journal of Poultry Science* **5** 1008-1015. https://doi.org/10.3923/ijps.2006.1008.1015

Corzo A, Kidd M T, Burnham DJ, Branton SL, Gonzalez-Esquerra R, Miller ER 2005: Dietary amino acid density effects on growth and carcass of broilers differing in strain cross and sex. *Journal of Applied Poultry Research* **14** 1-9. https://doi.org/10.1093/japr/14.1.1

Diaz M, Lopez F, Hernandez F, Urbania JA. 2000. L-carnitine effects of chemical composition of plasma lipoproteins of rabbit fed with normal

and high cholesterol diets. Lipids. 35:627–632. https://doi.org/10.1007/s11745-000-0566-2

Dozier WA, Corzo A, Kidd MT, Schilling MW 2008: Dietary lysine requirements of male and female broilers from forty-nine to sixty-three days of age. *Journal of Poultry Science* **87** 1385-1391. https://doi.org/10.3382/ps.2007-00529

Emmert JL Baker DH 1997: Use of the ideal, protein concept for precision formulation of amino acid levels in broiler diets. *Journal of Applied Poultry Research* **6** 462-470. https://doi.org/10.1093/japr/6.4.462

Emmert JL, Douglas MW, Boling SD, Parsons CM, Baker DH 1999: Bioavailability of lysine from a liquid lysine source in chicks. *Journal of Poultry Science* **78** 383-386. https://doi.org/10.1093/ps/78.3.383

Fernandez SR Zhang Y Parsons CM 1995: Dietary formulation with cottonseed meal on a total amino acid versus a digestible amino acid basis. *Poultry Science*, 74 1168-1179. https://doi.org/10.3382/ps.0741168

Han Y, Baker DH, 1991: Lysine requirements of fast-and slow-growing broiler chicks. *Poultry Science* **70** 2108-2114. https://doi.org/10.3382/ps.0702108

Hosseintabar B, Dadashbeiki M, Bouyeh M, Seidavi A, van den Hoven R, Gamboa S. 2015. Effect of different levels of L-carnitine and lysine-methionine on broiler blood parameters. Rev MVZ Córdoba. 20(3):4698–4708. https://doi.org/10.21897/rmvz.40

Htoo JK, Oleveira JP, Albino LF, Hannans MI, Barbosa NAA, Rostango HS 2016: Bioavailability of L-lysine HCL and L-lysine sulfate as lysine sources for growing pigs. *Journal of Animal Science* **94** (3) 253-256. https://doi.org/10.2527/jas.2015-9797

Karami M, Torki M, Mohammadi H. 2018. Effects of dietary supplemental chromium methionine, zinc oxide, and ascorbic acid on performance, egg quality traits, and blood parameters of laying hens subjected to heat stress. J Appl Anim Res. 46(1):1174–1184. https://doi.org/10.1080/09712119.2018.1481411

Kidd M, Kerr B, Halpin K, McWard G, Quarles C 1998: Lysine levels in starter and grower-finisher diets affect broiler performance and carcass traits. *Journal of Applied Poultry Research* **7** 351-358. https://doi.org/10.1093/japr/7.4.351

Latshaw JD 1993: Dietary lysine concentrations from deficient to excessive and the effects on broiler chicks. *British Poultry Science* 34 951-958. https://doi.org/10.1080/00071669308417655

Leclercq B 1998: Lysine: Specific effects of lysine on broiler production: comparison with threonine and valine. *International Journal of Poultry Science* **77** (1) 118-123. https://doi.org/10.1093/ps/77.1.118

Maynard CW, Latham RE, Brister R, Owens CM, Rochell SJ 2019: Effects of Dietary Energy and Amino Acid Density During Finisher and Withdrawal Phases on Live Performance and Carcass Characteristics of Cobb MV×700 Broilers. *Journal of Applied Poultry Research* **28** 729-742. https://doi.org/10.3382/japr/pfz025

Mc Donald MW 2007: Methionine supplements in chicken diets III. The biochemical difference in sulphur-amino acid metabolism between White Leghorns and Australorps. *Australian Journal of Agricultural Research* **9**(1) 161-169. https://doi.org/10.1071/AR9580161

Namroud NF, Shivazadand M, Zaghari M. 2008. Effects of fortifying low crude protein diet with crystalline amino acids on performance, blood ammonia level, and excreta characteristics of broiler chicks. Poult Sci. 87:2250–2258. https://doi.org/10.3382/ps.2007-00499

NRC 1994: Nutrient Requirements of Poultry. 9th Edition, *National Academy of Sciences*, USA 19-34.

Ojediran TK, Ojeniyi O, Ajayi AF Emiola IA 2018: Effect of varying dietary lysine on growth performance, nutrient digestibility,

organ weight and carcass characteristics of broiler chickens. *Nigerian Journal of Animal Science* **20** (4) 432-439.

Pirzado SA, Mangsi AS, Mughal GA, Tariq M, Kalhoro DH, Khaskheli GB, Barham GS 2016: Effect of lysine supplementation on growth and carcass yield of broilers. *International of Journal Poultry Science* 28 4: 3861- 3864.

Rostagno HS, Pupa JMR Pack M 1995: Diet formulation for broilers based on total versus digestible amino acids. *Journal of Applied Poultry Research* **4** 293-299. https://doi.org/10.1093/japr/4.3.293

SAS 2009: SAS Statistical Package. SAS Institute, Version 9.1.

Sigolo S, Deldar E, Seidavi A, Bouyeh M, Gallo A, Prandini A 2019: Effects of dietary surpluses of methionine and lysine on growth performance, blood serum parameters, immune response and carcass traits of broilers. *Journal of Applied Animal Research* **47** (1) 146-153. https://doi.org/10.1080/09712119.2019.1583571

Sterling K, Pesti G, Bakalli R, 2004: Performance of different broiler genotypes fed diets with varying levels of dietary crude protein and lysine. *Poultry Science* **85** 1045-1054. https://doi.org/10.1093/ps/85.6.1045

Tang MY, Ma QG, Chen XD, Ji C 2007: Effects of dietary metabolizable energy and lysine on carcass characteristics and meat quality in arbor acres broilers. *Asian- Australian Journal of Animal Sciences* **20** (12) 1865-1873. https://doi.org/10.5713/ajas.2007.1865

Wang ZR You JM, Qiao SY, Wang X 2007: Bioefficacy of L-lysine.H_2S0_4 relative to L-lysine. HCL in broiler chickens, estimated by slope-ratio model. *Journal of British Poultry Science* **48** 3 381-388. https://doi.org/10.1080/00071660701370517

Yuncong Yuan, Xiaoling Zhao, Qing Zhu, Juan Li, Huadong Yin, Elizabeth R. Gilbert, Yao Zhang, Yiping Liu, Yan Wang, Diyan Li, Zhiqing Yang, Gang Shu 2016: Effects of Dietary Lysine Levels on Carcass Performance and Biochemical Characteristics of Chinese Local Broilers. Italian Journal of Animal Science **14** 38-40. https://doi.org/10.4081/ijas.2015.3840

Zarghi H, Golian A, Nikbakhtzade M 2020: Effect of dietary digestible lysine on growth performance, blood metabolites and meat quality of broilers 23- 38 days of age. *Journal of Animal Physiology and Animal Nutrition* **104** (1) 156-165. https://doi.org/10.1111/pn.13214